

**Adapting North Carolina's Coastlines  
to a New Era of Sea Level Rise**

**By**

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of the University of North Carolina at Chapel Hill  
in partial fulfillment of the requirements  
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in the Department of City and Regional Planning.**

**Chapel Hill**

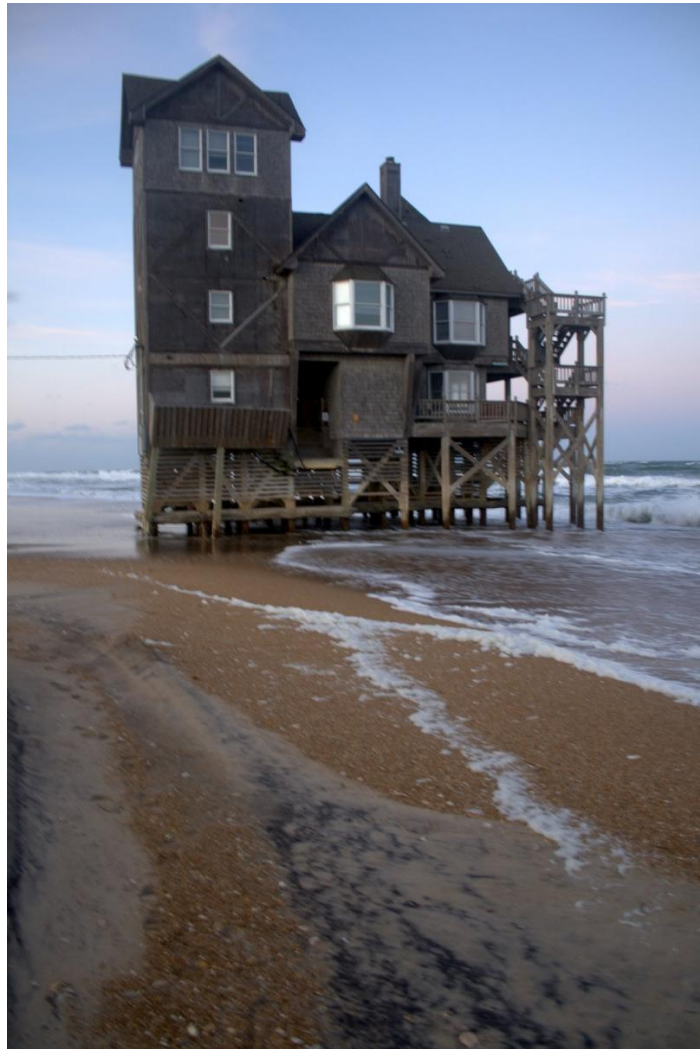
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## Introduction

Over the course of the next century, North Carolina's coastal communities will need to make difficult decisions about how they manage their land uses in response to projections of rising sea levels. As a consequence of sea level rise, researchers anticipate that the state's coastal municipalities will experience a multitude of physical changes, the most notable being the inundation of low-lying lands. Although 1 in 10 North Carolinians lives in an area where the state's Coastal Area Management Act (CAMA) oversees local land use planning, the certified CAMA land use plans include only a paucity of specific sea level rise adaptation provisions. Without proactive adoption of adaptation strategies at the local level, sea level rise has the potential to profoundly impact the quality of life for many of North Carolina's coastal residents.

Because land use policy decisions originate at the local level, land use planning will be the appropriate tool for responding to sea level rise. As such, North Carolina's coastal counties are currently at a critical juncture. As complex scientific uncertainty pervades attempts to accurately predict the extent of sea level rise and its associated impacts, many coastal residents and policymakers have understandably questioned the value of planning for sea level rise as the costs of change are steep. Should extra public funds be used to elevate bridges in anticipation of a high measure of sea level rise that may never occur? Is it worth the financial cost for a community to avoid an illegal takings challenge by purchasing land situated at 0.5 meters in elevation when sea level rise may only reach a maximum of 0.4 meters?

On the other hand, enough evidence exists to correlate accelerations in sea level rise with increases in global industrial activities (IPCC, 2007). Local land use preparations taken today may likely seem financially and socially inexpensive when compared to hastily funding the same interventions later in time should they become necessary. Should Morehead City expensively improve its wastewater network in an area of low elevation just to eventually relocate it when later evidence of inundation becomes more apparent? Will Elizabeth City be able to afford moving a school if it is sited on land that will soon be too unstable to support such a structure?

The connections between sea level rise adaptation and land use planning have been discussed by state officials as recently as March of 2010 when the Coastal Resources Commission's Science Panel on Coastal Hazards recommended that one meter be adopted as the amount of anticipated sea level rise by 2100 for the purposes of policy development and planning (Division of Coastal Management, 2010). Will the Division of Coastal Management accept the panel's recommendation? If so, will they provide a mechanism for reversing a trend in North Carolina that has made CAMA land use planning purely advisory and nonobligatory?

The objective of this report is to supply an in depth analysis of the need for incorporating sea level rise adaptation into local CAMA planning efforts based on the specific effects of sea level rise that North Carolinians are expected to experience over the next century. Moreover, this project is driven by the desire to serve the public interest by raising awareness of the vital role of planning in helping North Carolina's coastal communities to avoid experiencing calamitous outcomes associated with sea level rise.

Section 1 of this report begins with an assessment of how researchers believe that North Carolinians will experience sea level rise over the course of the next century. Section 2 discusses the role of CAMA land use planning in seeking adaptation solutions to sea level rise. Based on the effects of sea level rise specific to North Carolina mentioned in the first part of this report, Section 3 formulates broad goals to meet the state's adaptation needs and supplies recommendations for overcoming common adaptation planning obstacles. Lastly, section 4 highlights exemplary instances of innovative efforts to incorporate adaptation into local planning initiatives.



North Carolina's coastal plain includes 5,900 km<sup>2</sup> of land below 1 meter in elevation  
(Photo source: NOAA)

## **Section 1: The Need for CAMA Land Use Planning to Incorporate Adaptation**

The notion of an adaptive response to sea level rise first garnered attention in the IPCC's 2001 climate change assessment report. Broad support for adaptation did not gather momentum, however, until the IPCC's fourth installation in 2007, when evidence emerged suggesting the inevitability of sea level rise amidst the inability for atmospheric greenhouse gas concentrations to rapidly stabilize through any worldwide emissions reduction scenario (Blanco et al., 2009; Moser, 2005). Additionally, the absence of a serious global commitment to mitigating climate change through greenhouse gas reductions has encouraged many researchers to advocate for more attention to adaptation in policymaking (Patwardhan, Downing, Leary, & Wilbanks, 2009; Nicholls & Tol, 2006; Walsh et al., 2004).

Despite pessimistic IPCC projections, researchers note the necessity for governments to continue mitigating greenhouse gas emissions and climate change impacts in addition to engaging in adaptation planning, rather than selecting sea level rise policies through an either/or approach (Blanco et al., 2009). Instead, the IPCC has reminded policymakers that successful mitigation reduces the adaptation challenge, because a greater magnitude of climate change may render adaptation planning ineffective (2007). While a global response will be necessary for mitigating climate change, preparing North Carolina's vulnerable coastal lands for the impacts of sea level rise represents a local CAMA planning challenge, as inundation will most directly impact local land uses.

### ***How much sea level rise will North Carolina experience?***

A growing volume of scientific data suggests that global sea levels have been rising at an accelerated rate, largely in response to widespread combustion of fossil fuels. In its Fourth Assessment Report from 2007, the Intergovernmental Panel on Climate Change (IPCC) provided projections of 0.18 to 0.59 meters in sea level rise worldwide by 2100. Many climatologists have criticized these figures as overly conservative, however, because they exclude contributions from melting ice sheets (Kerr, 2007). More comprehensive attempts to gauge future sea level rise by accounting for the volume of water held in sheet ice, suggest a more likely figure of 0.83 meters (Pfeffer, 2008).

Just as no two geographic areas are alike, though, North Carolina's coastal communities will experience sea level rise differently than the global norm. Evidence indicates that North Carolina's northern and southern coastal plains are experiencing rates of sea level rise amongst the highest worldwide. Here, the measure of isostatic rebound, which describes regional movement of the earth's surface, accounts for an additional 0.2 meters in sea level rise each century. Consequently, North Carolina's coastal communities will more likely witness 0.3 to 1.1 meters in sea level rise by 2100 (Poulter et al., 2009).

### *How will North Carolina experience sea level rise?*

With more than 5,900 square kilometers of coastal plain below a meter in elevation and home to the second largest estuarine ecosystem in the United States, North Carolina remains particularly vulnerable to inundation as a consequence of sea level rise (Titus & Richman, 2001). As a result, widespread inundation will force the need for new policy to address a host of local physical land use planning challenges (Jacob, Gornitz, & Rosenzweig, 2007). Table 1.1 highlights some of these expected challenges. Researchers' attempts to quantify impacts into familiar units (ie. dollars, mileage, acreage) are highly dependent on a wide range of assumptions that reflect predicted changes, such as future population growth or transportation infrastructure demand. While heavily dependent on assumptions, the studies cited in this section can provide planners with important indicators of how communities will be impacted by sea level rise if adaptation does not occur through a planned approach.

Table 1.1 Planning challenges accompanying expected effects of sea level rise

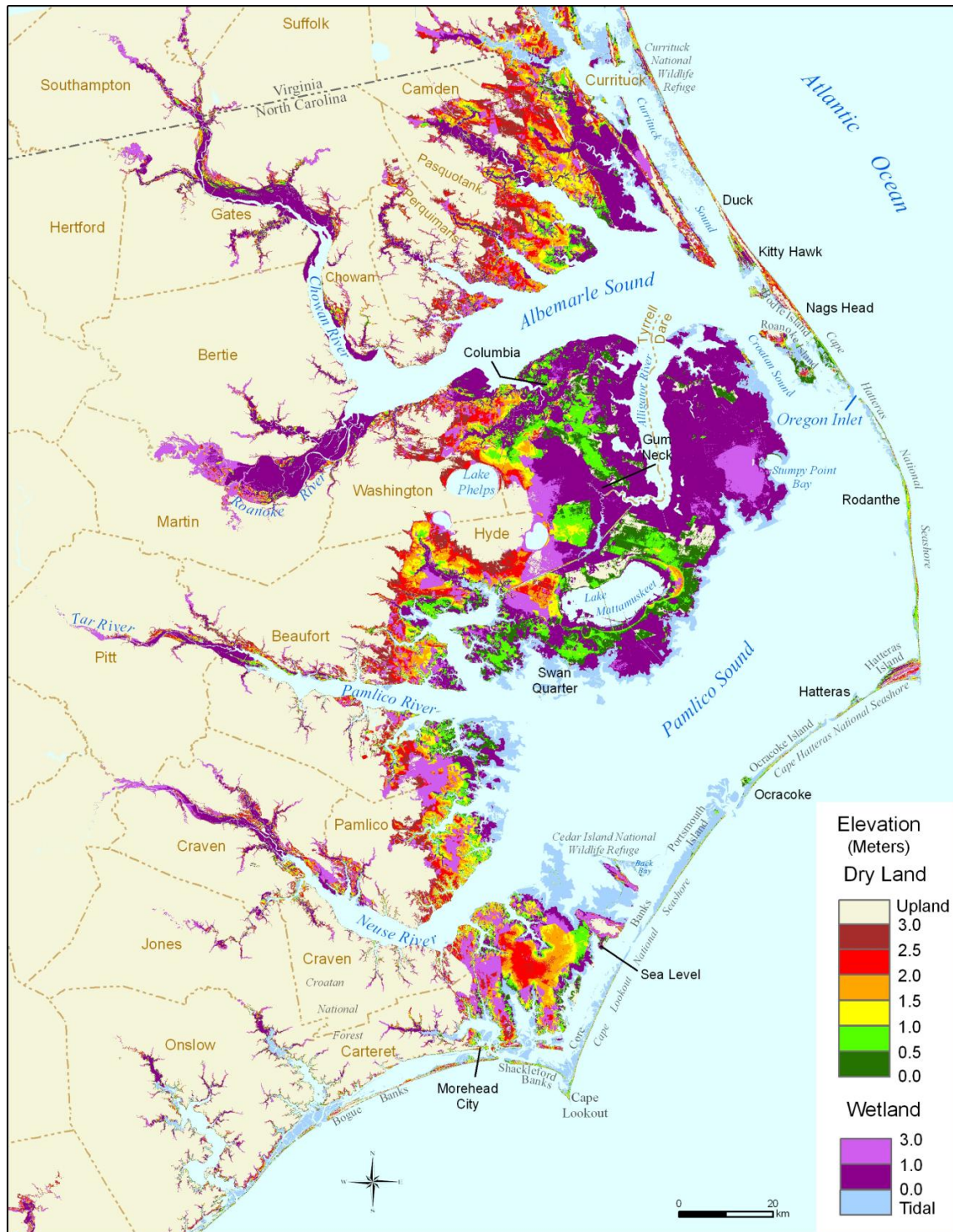
Impacted Area	Possible Characteristics	Planning Challenges
<b>Development and Infrastructure</b>	<ul style="list-style-type: none"><li>• Inundation</li><li>• Flooding</li><li>• Increased erosion</li><li>• More powerful storms</li></ul>	<ul style="list-style-type: none"><li>• New evacuation routes needed</li><li>• Damaged structures</li><li>• Obsolescence of structures</li><li>• Reduced property values</li></ul>
<b>Water Quality</b>	<ul style="list-style-type: none"><li>• Saltwater intrusion into aquifers</li><li>• Depletion of freshwater supplies</li></ul>	<ul style="list-style-type: none"><li>• Inadequate domestic supply</li><li>• Inadequate supply for industry</li><li>• Reduction in biodiversity</li><li>• Reduced agricultural productivity</li></ul>
<b>Ecosystems</b>	<ul style="list-style-type: none"><li>• Habitat loss</li><li>• Wetland destruction</li></ul>	<ul style="list-style-type: none"><li>• Loss of ecosystem services</li><li>• Reduction in biodiversity</li><li>• Reduction in ecotourism</li></ul>
<b>Physical Shorelines</b>	<ul style="list-style-type: none"><li>• Inundation</li><li>• Widespread flooding</li><li>• Increased erosion</li><li>• More powerful storms</li><li>• Collapse of the Outer Banks</li><li>• Habitat loss</li></ul>	<ul style="list-style-type: none"><li>• Increased need for hazard mitigation and response</li><li>• Loss of ecosystem services</li><li>• Loss of tourism attractions</li><li>• Ambiguity over public/private property ownership status</li></ul>

### *Impacts on Physical Shorelines*

The primary impact of sea level rise in North Carolina will be inundation of much of state's shoreline. Map 1.1 illustrates the elevations of North Carolina's coastal lands that are 3.0 meters or fewer in elevation. Areas shown in dark purple and green will be particularly prone to inundation.



Figure 1. Elevations of land close to sea level in North Carolina



#### Elevations of Land Close to Sea Level

Elevations are above spring high water, which is the average high tide during new and full moons, and approximately the inland boundary of tidal wetlands. This map is a general graphical representation of elevations in the area depicted, not designed to estimate the precise elevations at specific locations. Actual elevations at specific locations may be 30 cm above or below the elevation shown.

Source: J.G. Titus and J Wang. 2008. "Maps of Lands Close to Sea Level along the Mid-Atlantic Coast".

US Environmental Protection Agency.



The impacts of inundation on North Carolina's physical shorelines will be manifold, yet impacts may be mitigated if the Outer Banks are able to remain intact throughout the maximum extent of sea level rise. Some researchers have expressed concern that increases in storm events over the next century could cause breaches in the barrier islands (FitzGerald, Fenster, Argow, & Buynevich, 2008; Riggs & Ames, 2003). Breaches are cause for concern, because permanent breaching would transform the Albemarle-Pamlico Sound into a bay and further increase the salinity of the water (NCCOS, 2010). Additionally, Moore (2007) suggests that a collapse of North Carolina's barrier island system is possible in a 1.4 to 1.9 meter sea level rise scenario. Because the Outer Banks protect the mainland from experiencing higher tidal ranges, a collapse of the barrier island system could increase sea levels in the Albemarle-Pamlico Sound by an additional 1.25 meters.

Many of North Carolina's coastal communities depend on the physical shoreline for supporting their large recreation and tourism industries. Consequently, sea level rise will cause the state to suffer tremendous financial loss through increased erosion, narrowing of beaches, and loss of fishing locations. Bin (2007) estimates that the state's coastal tourism industry—which CAMA counties are heavily reliant upon for income—could lose \$10.6 billion (2008 dollars) with an 18-inch (.47 meter) rise in sea level.

#### *Impacts on Development and Infrastructure*

In addition to inundation of portions of the built environment, North Carolinians will likely experience increased susceptibility of development and infrastructure to other hazards, such as flooding, coastal erosion, and storm events (Hopkinson, Lugo, Alber, Covich, & Van Bloem, 2008). Properties situated along North Carolina's coast are particularly vulnerable to sea level rise. Bin (2007) estimates that an 18-inch (0.46 meter) rise in sea level by 2080 would result in a loss of \$2.8 billion (2007 dollars) in property values to New Hanover, Dare, Carteret, and Bertie Counties alone. Table 1.2 shows a summary of his findings.

Table 1.2 Estimates of lost coastal property value, 2080, 18-inch sea level rise scenario in four North Carolina counties

County	Residential Property Value Loss	Non-Residential Property Value Loss
<b>New Hanover</b>	\$99 million	\$35 million
<b>Dare</b>	\$988 million	\$1.42 billion
<b>Carteret</b>	\$100 million	\$183 million
<b>Bertie</b>	\$5.45 million	\$3.8 million

Source: Bin et al., 2007, converted to 2007 dollars

Similarly to development, inundation poses a serious threat to public infrastructure through potential to cause damage or obsolescence. Additionally, weakened or destroyed infrastructure may also cause coastal property values to decline. Adapting roadways to sea level rise is particularly important for the purpose of maintaining access to coastal communities, especially during evacuation scenarios (Titus, 2003). Table 1.3 illustrates the amount of state transportation infrastructure that would be inundated or at-risk of damage from flooding if sea levels were to rise by 48.5 centimeters.

Table 1.3 Estimates of transportation infrastructure susceptible to inundation

Category	Inundated	Percent of Related Infrastructure
<b>Roadway</b>	560.8 miles	15%
<b>Railway</b>	120.4 miles	2%
<b>Airports</b>	2,147 acres	10%
<b>Ports</b>	320 acres	70%

Source: Savonis, 2008.

#### *Impacts on Water Quality*

North Carolina's coastal municipalities will need to make preparations for a potentially sharp degradation in water quality and freshwater availability over the next century. As sea level rise inundates North Carolina's vast coastal plain, the groundwater table will rise, advancing intrusion of saltwater (Maryland Commission on Climate Adaptation and Response, 2008). Increased tidal ranges expected for the state's estuarine shorelines will also advance saltwater intrusion. An increase in tidal ranges will likely facilitate the landward migration of saltwater into aquifers, which coastal North Carolinians heavily depend upon for their freshwater needs (Titus, 1990; North Carolina Rural Economic Development Center, 2006). At this time, the literature reveals little information concerning quantifiable projections of future saltwater intrusion into North Carolina's coastal aquifers; however, Gornitz (1991) suggests that the ability for freshwater to remain separated from the denser saltwater in water tables reduces by 40 times the measure (in centimeters) of sea level rise.

As North Carolina's most productive cropland, coastal residents depend on availability of freshwater to support agricultural activities (Street, Deaton, Chappell, & Mooreside, 2005). Saltwater intrusion presents a threat to agriculture by degrading the productivity of agricultural fields. Advances in sea level rise may necessitate a shift to more salt-resistant, and possibly genetically modified, crops (IPCC, 1990).

### *Impacts on Ecosystems*

Degradation of water quality is also intricately linked to the health of North Carolina's numerous delicate ecosystems and their ability to support biodiversity. Vegetation changes will modify the composition of wildlife populations that have adapted to specific plant associations over time (USGS,1997). Evidence of destruction of coastal forests from sea level rise is already visible along the Cape Fear River where estuarine shorelines are lined with dying cypress trees that have been unable to withstand saltwater intrusion (D. Springer, personal communication). Elsewhere, the coastal treeline is migrating landward at a rate of about 1 to 12 meters per year (Poulter, 2005). With cypress tree mortality attributable to saltwater intrusion already occurring 10 miles northwest of the Port of Wilmington, it is highly likely that sea level rise will bring widespread habitat loss.

Most researchers agree that sea level rise will be destructive to North Carolina's coastal wetlands. The combined forces of sea level rise and shoreline hardening technology (ie. bulkhead construction) currently destroy 1.25 square miles of wetlands each year along North Carolina's estuarine shoreline where CAMA does not forbid shoreline protection (Riggs & Ames, 2003). The available literature cannot accurately predict future wetland loss in North Carolina to sea level rise because the rate will be dependent on sediment supply and transport to wetland surfaces, and thus their ability to accrete. Donnelly and Berness (2001) suggest that the rate at which sea level rise accelerates will determine the future condition of wetlands, with a higher rate making it less likely that lowland marsh will survive.

Sea level rise will eliminate the availability of numerous ecosystem services. If wetlands are destroyed, coastal communities will also lose the natural water filtration, flood protection, and carbon sequestration that are otherwise supplied. A number of federally and state recognized species of concern that attract visitors to the coast, such as sea turtles and venus fly traps, will also suffer as valuable habitat is lost to sea level rise.

## **Section 2. The Role of CAMA Land Use Planning in Sea Level Rise Adaptation**

Because of unpredictable future greenhouse gas emissions and complex interactions between melt from ice sheets and receiving oceans, most climatologists agree that it is nearly impossible to accurately predict the timing of sea level rise experiences using the present generation of modeling technology. In Beaufort County, for example, there is a 50-year window of uncertainty surrounding projections for overtopping of a local dike (Poulter & Halpin, 2008). Such uncertainty illustrates the necessity for North Carolinians to adapt to scientific projections of sea level rise and form policies in response to the expected impacts described in Section 2 as early as possible. Accordingly, land use planning will play a critical role in the adaptation process.

Effective land use planning has the ability to address a breadth of complex and multifaceted local challenges unlike any other policy tool. Because of its place-based purview, relying on CAMA land use planning to establish local adaptation policies represents a more appropriate option than doing so at the state level. Additionally, knowing that each locality will have its own unique experiences with sea level rise, communities will need the flexibility offered by local land use planning in selecting their respective adaptation strategies.

Before turning to the general adaptation goals needed within the local CAMA land use plans in anticipation of an era of accelerated sea level rise, it is important to provide an overview of their historical context and present role in managing North Carolina's coastal resources. Although this report identifies a general lack of sea level rise preparedness as a major shortcoming in the CAMA land use planning process, North Carolina's coastal resource management program should be considered far from a failure. Importantly, CAMA has succeeded in establishing a necessary framework for mandating land use planning and considering environmental hazards in a geographic area of the state where communities had little experience with planning, subdivision ordinances, and zoning prior to the mid-1970's.

### **CAMA Land Use Planning**

#### ***Background***

At the time of its passage by the North Carolina General Assembly in 1974, CAMA was the most intensely debated environmental bill in state history. Considered highly progressive at the time, CAMA provided a framework for designation and regulation of critical areas of environmental concern (AEC) and mandated comprehensive local land use planning for the state's twenty coastal counties. Federally approved in 1978 by the Office of Ocean and Coastal Resource Management, CAMA established a Coastal Resource Commission (CRC) of fifteen

governor-appointed members to set standards (with guidance from a Coastal Resources Advisory Council) for the coastal counties to meet in formulating their land use plans. North Carolina's Department of Coastal Management (DCM) was designated as the lead agency, responsible for providing financial and technical assistance for CAMA land use planning efforts (Beatley, Brower, & Schwab, 2002).

Researchers and coastal managers in North Carolina were studying sea level rise and spreading awareness of its potential impacts during the early years of CAMA, yet sea level rise provisions were not incorporated into CAMA land use planning until the 1990's when coastal counties were first mandated to give consideration to mitigating its associated impacts. This rudimentary provision was weak, however, as it was identified as a local prerogative unenforceable by the state. Moreover, most communities determined that it was most prudent to forgo making any land use decisions related to sea level rise until a later point in time when more concrete research could be made available. Poulter attributes the lack of priority given to sea level rise planning to the general absence of climate change in the popular political dialogue of the 1990's (2008). Instead, Moser suggests that attention to the problem of sea level rise has been historically overshadowed by issues related to short-term hurricane recovery, property rights battles, and water quality concerns (2005).

The local land use planning provision of CAMA in particular was expressly adopted to "give special attention to the protection and appropriate development of areas of environmental concern." An excerpt of the legislative history reveals the General Assembly's motivation in passing CAMA:

"The 1974 Legislature found that the coastal area, and in particular the estuaries, are among the most biologically productive regions of this state and of the nation, but in recent years the area has been subjected to increasing pressures which are the result of the often conflicting needs of society expanding in industrial development, in population, and in the recreational aspirations of its citizens. Unless these pressures are controlled by coordinated management, the act states, 'the very features of the coast which make it economically, aesthetically, and ecologically rich will be destroyed.'

Early on, these principles faced intense opposition from local coastal governments who felt that they were being unfairly required to infringe upon the rights of private property owners within their jurisdictions (D. Brower, personal communication, February 25, 2010). Nevertheless, the state legislature embraced county-level land use planning as the most effective tool for managing localized land use challenges in the long run.

***How are CAMA plans assembled?***



The DCM describes CAMA land use plans as the collection of policies and maps that serve as a coastal community's blueprint for growth. Because policies contained within CAMA land use plans are decided by local residents, it is crucial that planners engage stakeholders in a well-informed public dialogue. (Issues related to information and stakeholder education will be further expanded upon in Section 3.) Once the community determines its preferred policies, the CRC can decide whether to approve the plan based on its success in meeting state criteria. If the plan is approved, the DCM uses it as a guiding document for issuing development permits.

All local CAMA land use planning is inherently guided by outcomes from the critical public participation process. This engagement with the public is mandatory for the local government to be eligible to receive "CAMA funds" from the state. Driven by public participation, CAMA land use plans are required to have four general sections: "Community Concerns and Aspirations", "Analysis of Existing and Emerging Conditions", "Plan for the Future", and "Tools for Managing Development". Within the "Community Concerns and Aspirations" section, citizens offer their comments concerning the six CAMA "Management Topics": "Public Access", "Land Use Compatibility", "Infrastructure Carrying Capacity", "Natural Hazard Areas", "Water Quality", and "Areas of Local Concern". "Management Topics" are then reintroduced in the "Plan for the Future".

### *How does CAMA address sea level rise?*

A primary criticism of CAMA land use planning thus far amongst sea level rise adaptation and mitigation proponents has been the noted exclusion of sea level rise as an identified hazard in most certified plans. This general nonconsideration of sea level rise is likely attributable to its omission from the DCM's Technical Manual for Coastal Land Use Planning, which CAMA counties depend on for guidance throughout the planning process (DCM, 2002). Nevertheless, some CAMA counties have taken the initiative to make more substantial preparations for adapting to and mitigating sea level rise despite weak prescriptions by the state.

The certified Wilmington-New Hanover County CAMA plan is one such example. Unlike most other CAMA counties, New Hanover County elaborates upon sea level rise in the hazards section of its land use plan by identifying sea level rise projections and solutions for mitigating losses to its potential impacts. Within the Wilmington-New Hanover plan, mitigative solutions include hardened structures to protect the estuarine shoreline where retreat is deemed unfeasible, while adaptive approaches involve increased setbacks and fee-simple purchase of low-lying lands where shoreline retreat is possible.

Despite CAMA's historically weak consideration of sea level rise, within the last few years it has become a more prominent consideration in other state coastal management policy decisions. The dissemination of advanced research has

provided valuable information to stakeholders, thus enabling a well-informed public dialogue about the importance of addressing sea level rise through adaptation in addition to mitigation. Although relatively few adaptation policies and strategies have yet been incorporated into certified CAMA land use plans, the increasing prevalence of sophisticated sea level rise research, popular dialogue concerning solutions, and a more favorable political climate than in previous years have given stakeholders a more complete understanding of the need to plan for sea level rise. Consequently, stakeholders in CAMA counties are seeking political responses to sea level rise now more than ever before.

The literature indicates that the time is now ripe for new sea level rise solutions to be included within CAMA land use planning as momentum in sea level rise discussions has opened a policy window (Moser 2005). Importantly, sea level rise is already mentioned within the state's primary CAMA land use planning objective, which will ease the process of planning new solutions. Accordingly, the administrative code prioritizes "[d]evelop[ing] policies that minimize threats to life, property, and natural resources resulting from development located in or adjacent to hazard areas, such as those subject to erosion, high winds, storm surge, flooding, or sea level rise." This statutory language is significant since it precludes the necessity to rewrite coastal policy to mandate sea level rise planning.

### **Section 3. Policy Options for Adaptation**

Having established the need and prudence for CAMA land use planning to counter future sea level rise scenarios with an approach that prioritizes adaptive response, this section of the report introduces a series of possible adaptation goals and supporting policies for North Carolina's coastal communities to use in considering the effects (discussed in Section 1) of sea level rise during the next century. Each set of goals and policies is accompanied by a sampling of programs and implementation actions that other coastal communities have adopted, some in anticipation of physical changes to their own shorelines. Recognizing that many obstacles, both general and specific to North Carolina, will likely continue to hamper efforts to meaningfully implement planning policies related to sea level rise, this section of the report also offers recommendations for countering such challenges.

Because policies designed to address one adaptation planning goal may in turn support another, the sea level rise adaptation goals listed in this section are in no particular order of priority.

### Proposed Adaptation Goal #1:

*Structurally sound and safely sited development and infrastructure in harmony with the surrounding ecology*

**Proposed Policy #1:** Improve availability of hazard information to the public

**Proposed Policy #2:** Form partnerships with local, regional, and state agencies to reduce likelihood of structural damage from flooding, erosion, and storms

**Proposed Policy #3:** Restrict major infrastructure investments near the shorelines

Table 3.1. Sample programs and actions to support Goal #1 in adapting to the impacts of sea level rise on North Carolina's coastal development and infrastructure

Action	Pros	Cons	Examples of Implementation
<b>Require new infrastructure investments to consider impacts of sea level rise</b>	Protects public investment from risk; May spurn new innovation in engineering	Politically infeasible to deny affected coastal landowners of infrastructure needs	Marin County, California; King County, Washington
<b>Use site/project review to ensure safety of development</b>	Reduces risk of development	Requires trained staff; Delays development process	Berkeley, California;
<b>Form sea level rise inundation maps</b>	Informs development siting process	Requires trained staff;	San Francisco, California
<b>Initiate a public acquisition program for converting sensitive lands to open space</b>	Prevents future structural loss; Could provide a protection buffer for properties located further inland; Creates open space	Highly expensive; Reduces tax base; Risky investment if sea level rise does not impact purchased land	Deer Island, Mississippi; Miami-Dade County, Florida

## Proposed Adaptation Goal #2:

*A high level of water quality supportive of domestic, agricultural, industrial and ecological needs*

**Proposed Policy #1:** Protect local water supply from contamination

**Proposed Policy #2:** Protect lands that are subject to flooding

**Proposed Policy #3:** Conserve water use where possible

Table 3.2: Sample programs and actions to support Goal #2 in adapting to the impacts of sea level rise on North Carolina's water quality

Option	Pros	Cons	Examples of Implementation
<b>Invest in</b> desalination technology to fulfill water supply needs	Expands water supply; Reduces stress on aquifers	Highly expensive; High energy intensity may counter greenhouse gas emission reduction progress	Hillsborough County, Florida
<b>Use recycled</b> water to replenish groundwater	Reduces stress on aquifers; Provides protection against saltwater intrusion	Extensive public education and vetting; Expensive technology	Monterey, California
<b>Acquire land for</b> aquifer recharge	Improves quantity of water supply; Provides open space	Acquisition of land is expensive and difficult to justify leaving as open space	Polk County, Florida
<b>Replace</b> impervious surfaces with photocatalytic technology	Reduces flooding; Beneficial for cleansing stormwater	Initially expensive; May be difficult to justify as a priority expenditure	Chicago, Illinois
<b>Use "grey</b> water" for irrigation purposes	Reduces the amount of freshwater needed for agriculture	"Grey water" system may be expensive to construct	Los Angeles, California



### Proposed Adaptation Goal #3:

*A healthy natural environment supportive of restoring and maintaining a balance of ecosystem services, recreational use, and economic opportunity*

**Proposed Policy #1:** Preserve and expand wildlife habitats where possible

**Proposed Policy #2:** Maintain resilience of biodiversity

**Proposed Policy #3:** Establish land use densities appropriate for maintaining balance to nearby ecosystems

Table 3.3: Sample programs and actions to support Goal #3 in adapting to the impacts of sea level rise on North Carolina's ecosystems

Option	Pros	Cons	Examples of Implementation
<b>Merge wetland</b> protection into infrastructure planning initiatives	Supports preservation of wildlife habitat; Protects water sources from contamination	May increase expense of infrastructure investment	Houston-Galveston Regional Transportation Plan
<b>Require all</b> tidelands to be left in their natural state	Maintains protective qualities of tidelands for inland ecosystems	Politically difficult to require valuable land to remain as open space	Marin County, California
<b>Introduce</b> sediment to facilitate vertical wetland accretion	Expands wildlife habitat; Beneficial to water quality	Requires continuous recharge to be effective	Louisiana
<b>Establish</b> species recovery plans	Beneficial to maintaining biodiversity; Provides research opportunities	Potentially expensive; Difficult to set benchmarks for progress against uncertainty of climate changes	King County, Washington

#### Proposed Adaptation Goal #4:

*Development of land in accordance with a living shoreline*

**Proposed Policy #1:** Control shoreline modification in a planned approach

**Proposed Policy #2:** Prioritize development retreat from shoreline encroachment

**Proposed Policy #3:** Concentrate development in designated urban corridors

Table 3.4: Sample programs and actions to support Goal #4 in adapting to the impacts of sea level rise on North Carolina's physical shoreline

Programs	Pros	Cons	Examples of Implementation
<b>Establish</b> rolling easements	Protects tidelands from wetland destruction caused by hardened structures; Provides optimal safeguard for ecosystem services; Low risk if sea level rise occurs at a low rate	Potentially expensive depending on scale of use; Does not protect communities from saltwater intrusion	Texas Open Beaches Act; Worcester County, Maryland; South Carolina
<b>Remove</b> bulkheads and other hard shoreline protection structures to promote shoreline migration	Facilitates sediment transport for vertical accretion of wetlands; Maintains concept of the living shoreline	Politically challenging to advance a policy that will be destructive to shoreline property; Public funds needed for removing structures	King County, Washington
<b>Establish</b> criteria for allowing some shoreline protection	Protects development and infrastructure; Calming of wave action benefits marshland	Destructive to the coastline; Facilitates loss of habitat	Northumberland County, Virginia

## **Obstacles**

As mentioned in Section 1 of this report, only a paucity of combined adaptation and mitigation strategies have been designed to prepare North Carolina's coastal communities for the impacts of sea level rise. To facilitate the necessary changes that must be made to the CAMA land use planning process and protect public interests threatened by sea level rise, it is important to first understand what obstacles have led to a lack of adaptive responses thus far. Recognizing that many obstacles, both general and specific to North Carolina, will likely continue to hamper efforts to meaningfully implement planning policies related to sea level rise, this section of the report also offers recommendations for countering such challenges. Recommendations listed in this section are not intended to provide an exhaustive list of remedies for advancing adaptation planning in an era of heightened awareness of sea level rise, but rather they are intended to provide a starting point for advancing the discussion about what fundamental changes must be made to CAMA land use planning.

### **Obstacle 1: Enforcement**

A consistent criticism of CAMA has been its lack of an enforcement mechanism for carrying out the provisions contained within certified land use plans. Without enforceable policies, CAMA land use plans are effectively advisory in purpose only. CAMA counties in particular have been historically resistant to placing restrictions on development and proactively responding to projections of local sea level rise. Consequently, it is not uncommon for CAMA communities to construct their land use plans around preexisting community ordinances instead of guiding the creation of new ordinances to meet coastal management objectives. Some of North Carolina's larger and more rapidly growing jurisdictions have gone beyond the state's requirements and adopted their own implementation ordinances because they felt that it was proper (Beatley, Brower, & Schwab, 2002). Many communities, however, have not taken such initiative. This enforcement obstacle will need to be overcome at the state level rather than locally.

### *Recommendation:*

If North Carolina's coastal communities are to be prepared for adapting to sea level rise, the state will need to improve its CAMA land use planning guidelines by strengthening policy implementation and enforcement rules. Excessive variance granting is also an obstacle to meaningful enforcement of adopted policies. In its 2006 evaluation of the state's coastal management program, NOAA advised the Coastal Resource Council to exercise more restraint in granting variances to CAMA development restrictions. Because the Coastal Resource Council should focus its attention on management needs for preparing the state to adapt to sea level rise and other emerging issues, NOAA recommended that the state create a specialized subcommittee to handle variance requests in a planned manner rather than on a

case-by-case basis. NOAA's recommendation would provide a valuable improvement to the CAMA planning process.

### **Obstacle 2: Education and Misinformation**

Engagement of stakeholders is a critical component of any attempt to incorporate sea level rise preparedness into land use planning. Adaptation and mitigation interventions will inherently require support and consent from residents who live, work, and access low-lying areas threatened by sea level rise. A high level of collaboration between stakeholders and local government in adaptation and mitigation planning can enhance the CAMA land use plan's authoritativeness and better ensure that recommended interventions become implemented. Accordingly, it is important that stakeholders receive objective information and remain knowledgeable about the dangers that sea level rise poses to low-lying coastal communities, despite its complexities and uncertainties.

Citizens will need to be knowledgeable in order to for adaptation to be prioritized within their communities. A survey conducted by the Institute for the Environment designed to capture public perceptions concerning sea level rise amongst residents living in the Outer Banks found a correlation between educational attainment and basic knowledge of sea level rise. The same survey also found that people with lower levels of educational attainment were typically less concerned about its cumulative impacts. While most people surveyed confirmed their belief in the ongoing phenomenon of sea level rise, the researchers noted that many people believed that there was too little data available to make an informed decision (Barber et al., 2008).

Further obfuscating knowledge of sea level rise, and thus the ability to prepare for its impacts, have been prominent instances of organized sowing of confusion and misinformation by climate "skeptics" and conservative think-tanks. Numerous high profile examples of deliberate attempts at the federal level to raise doubt about climate change and sea level rise over the last decade have become prominently featured in recent news reports. Although some action will need to be taken at the ballot box to advance preparations for sea level rise, the most effective solution will involve expanding one's knowledge.

### *Recommendation:*

Knowledge is key to adaptive capacity (Smith and Lenhart, 1996; Smith et al., 2001). If adaptation and mitigation are to be meaningfully incorporated into CAMA land uses, public dialogue with a well-educated public will play a critical role in advancing policy changes. In adapting to climate change, perfect data concerning precise outcomes is unnecessary, because enough data exists to know the imminence of sea level rise and which areas will be most vulnerable (Frumkin,

2010). Climate literacy and education will need to be maintained in several capacities if this obstacle is to be overcome.

Planners have the training, long-range outlook, and technical aptitude to advance education and dispel misinformation related to sea level rise. In addition to explaining challenges and comprehensive solutions through planning documents, computer technology must play a central role in informing stakeholders about the local consequences of sea level rise. The literature suggests that the most effective method for generating climate change policy support is to associate its risks with citizens' abilities to carry on their ordinary well-beings (Zahran, Brody, Grover, & Vedlitz, 2006). Visually modeling impacts of sea level rise using Geographic Information Systems (GIS) can provide user-friendly and convincing evidence of such risks. North Carolina's coastal planners should use tools like GIS to visually illustrate sea level rise inundation as a development hazard.

Lastly, CAMA land use plans should be crafted to enhance their readability so that they may be more easily understood by the general public. Goals, policies, objectives, and supporting text should be neatly organized and visually appealing in an effort to optimally convey important information about the future direction that the community will take in facing its unique challenges (Berke, Godschalk, & Kaiser, 2006). More user-friendly CAMA plans have a greater likelihood of educating stakeholders about community challenges and encouraging them to contribute to discussions concerning solutions.

### **Obstacle 3: Human Response to Uncertainty**

Similar to the inefficiencies that behavioral economists often describe in human and organizational behavior, adaptive response to sea level rise is confounded by a strong bias for communities to maintain the status quo. Momentous changes in behavior and policy are more likely to occur following a single major storm event, such as a hurricane, than the high cumulative probability of sea level rise in the future. North Carolina's experiences with Hurricane Floyd in 1999 provide a good example to illustrate this point. In partial response to the \$3.5 billion (1999 dollars) in damage caused by Hurricane Floyd, the state invested \$70 million in LIDAR technology to correct for the numerous inaccuracies in its previous flood maps that the storm revealed (Thompson & Maune, 2000). On the hand, CAMA land use plans continue to remain largely void of sea level rise policies despite a growing volume of evidence supporting the occurrence of future impacts to North Carolina.

#### *Recommendation:*

Planning for adaptation will need to be creative and incorporate as many management goals as possible to counter the uncertainty surrounding sea level rise. For instance, Houston and Galveston have incorporated a wetland protection



provision into their long range transportation plan to reduce the impacts of transportation on sensitive habitats. In turn, this adaptation serves the dual purpose of preserving wildlife habitat and maintaining the water purification services provided by wetlands.

Increased research will also be important overcoming sluggish response to uncertainty. A major hindrance to incorporating sea level rise adaptation into land use planning efforts thus far has been a lack of research on the financial risk of adaptive response. Many of the adaptation cost-benefit analyses to date are global in focus and have little practical relevance to planners who work at a local scale. For policymakers to embrace adaptation, more research will be needed from academic authorities concerning the costs and benefits of sea level rise adaptation strategies best practices for timing in implementing policies, training, and funding.

#### **Obstacle 4: Economic Downturn**

Like other states across the nation, North Carolinians have suffered financially as a result of the global financial crisis. From the outbreak of the crisis in late 2007 to early 2010, approximately 275,000 jobs were lost across the state (North Carolina Employment Security Commission, 2010). Unsurprisingly, polling data from the 2008 presidential and state elections revealed that North Carolinians were primarily concerned with the economy more than other issues facing the state. Recently, officials such as United Nations' Framework Convention on Climate Change executive secretary Yvo de Boer have expressed concern that governments may shift funding devoted to climate change initiatives to boosting their financial systems (Kanter, 2008). As a consequence, planners will need to be creative and informative in explaining the necessity for adapting to sea level rise as a wise investment in present and future public funds.

#### *Recommendation:*

The primary financial value of adaptive response to sea level rise is in the avoidance of damage and subsequent costs that would occur if development were to continue without sufficient intervention. As such, by delaying action on sea level rise as many CAMA land use plans do, the impacts of sea level rise may be more costly than taking anticipatory action in the present. It is imperative that North Carolina's coastal policymakers understand that sea level rise adaptation is not a smooth, cost-free process. Few studies have been undertaken to quantify the cost of adapting to climate change and the financial risk of not doing so. Titus and Greene (1989) posit that making adaptive preparations for sea level rise in the present would be 60 to 75% less expensive than adapting in the face of a clear and present threat.

Efforts to plan for sea level rise are confounded by a wide range of uncertain variables, which in turn create questions of accuracy in predicting its impacts and

doubts concerning its prudence as an investment priority. Like most governments around the world, coastal counties in North Carolina have been reluctant to embrace adaptive responses to sea level rise without more certainty of consequences and risks. Dare County's CAMA land use plan, for example, states its sea level rise response policy in the following way:

"Policy 2.1.1 (c) Dare County believes that there is insufficient, reliable data to quantify the rate of sea level rise. The phenomenon needs additional study. Until a more reliable and conclusive database has been established, Dare County will continue to rely on AEC standards to rely on AEC standards [sic] for development limitations."

Nevertheless, because of its correlation to coastal elevation, sea level rise, similarly to flooding, may be one of the most predictable hazards to plan for. As such, planners have the opportunity to assume a leadership role in helping to abate the high costs anticipated as a result of sea level rise, particularly to the tourism, recreation, and real estate industries along North Carolina's coast.

## Section 5. Successful Models of Adaptation Planning

In addition to overcoming the obstacles listed in Section 4, North Carolina's coastal planners will need to apply their unique skill set in creatively and comprehensively tailoring solutions to meet their community's needs while addressing both adaptation and mitigation in response to new knowledge about sea level rise. Planners have a tendency to approach climate change from a completely mitigatory standpoint through measures such as green building codes and methods for reducing vehicular miles traveled (Shuford, 2010; Cruce, 2009). Inasmuch, hundreds of cities across the nation are (importantly) in the process of developing climate action plans, which are designed to direct policy toward reducing greenhouse gas emissions. Few coastal planning efforts, however, contain policies and actions to respond to specific local impacts of sea level rise (Deyle, Bailey, & Matheny, 2007). The three examples highlighted within this section are notable for their exemplary efforts in sea level rise adaptation planning at a local level.

### *King County, Washington*

Within recent years King County, Washington, has become one of the nation's foremost leaders in sea level rise adaptation planning. Included within King County's jurisdiction is the city of Seattle, making it the fourteenth most populous county in the nation. Surrounded by 2,000 miles of shoreline, King County's population is also highly vulnerable to the effects of sea level rise. In response, the county government formed an interdepartmental climate change adaptation team in 2006 with the intent of melding scientific research with planning, policy, and local capital investment decisions in the King County Climate Plan Program. In addition to setting actions and goals for strategic focus areas, including public health, surface water management, finance, and ecology, King County has prioritized sea level rise considerations in land use planning. The county government reviews all land use plans, policies, and investments to ensure that climate change impacts are considered or included. To implement its adaptation policies, King County has partnered with the Climate Impacts Group at the University of Washington.

Sea level rise projections are directly addressed through actions in the county's King County Climate Plan, transportation infrastructure plans, hazard mitigation plans, and others. Specific examples of policies and actions include:

- Ensuring consideration of sea level rise prior to initiating major public infrastructure construction and maintenance
- Encouraging shoreline stabilization structures to be relocated outside of the two-foot sea level rise inundation area
- Notifying prospective developers along Vashon and Maury Islands when development may be impacted by future sea level rise

- Mandating consideration of sea level rise implications in habitat protection and restoration projects

Together, these policies and others alike form a detailed action plan and a guide for local government in responding to sea level rise.

### *Punta Gorda, Florida*

With assistance from the EPA, the Southwest Florida Regional Planning Council and the Charlotte Harbor National Estuary Program developed a climate change adaptation plan for the city of Punta Gorda, which was released in November of 2009. Because the Southwest Florida Regional Planning Council is a quasi-governmental organization designed to provide input into state policy development, Punta Gorda's adaptation plan could not contain an implementation and enforcement mechanism for the policies contained within. The effort is notable, however, as an example of how a coastal community can develop an adaptation plan that actively engages stakeholders in the planning process and uses technology to illustrate challenges posed by sea level rise.

Through a series of public workshops and public meetings, the Punta Gorda adaptation planning team sought informed input from a host of stakeholders ranging from local retirees to members from the real estate sector. Their goal was to involve as much of the public as possible to encourage a public buy-in. Through a series of "games" played at local workshop events, the planning team incorporated GIS-generated maps to learn about which vulnerabilities and policies were most meaningful to the stakeholders. Games such as "The Adaptation Game" served the dual purpose of receiving feedback while concurrently informing stakeholders of critical information about the impacts of sea level rise. Based on the outcomes of the workshop games, stakeholders were able to select the most appropriate adaptations for their community to respond to pressing vulnerabilities.

As a result, stakeholder prioritized the following adaptations:

- Explicitly indicating in the comprehensive plan which areas will retain natural shorelines
- Constraining location for certain high risk infrastructure
- Seagrass protection and restoration
- Xeriscaping and native plant landscaping
- Restricting fertilizer use

Although mostly informative, the Punta Gorda adaptation planning effort contains lessons for North Carolina's coastal planners about engaging stakeholders in preparing for sea level rise. Planners will need to creatively engage stakeholders and transmit information in an easily understood and relatable manner. Punta

Gorda's adaptation plan also illustrates the necessity for North Carolina's planners to assess community vulnerabilities to sea level rise.

### *Marin County, California*

Choosing the theme "planning sustainable communities" for their countywide planning update in 2000, Marin County, California, opted to construct its entire comprehensive plan around the notion of sustainable development. Rather than crafting a single sustainability or climate change element, different notions of community-defined sustainability pervade the Marin Countywide Plan. The twelve community-defined principles and eleven countywide planning goals (based on the principles) each address the county's role in both mitigating the impacts of and adapting to the effects of climate change projected for the Bay Area. Specific sea level rise adaptation policies crafted to meet countywide planning goals include:

- "Consider sea level rise in future countywide and community plan efforts. Consider revising Marin County Development Code standards for new construction and substantial remodels to limit building or require elevated buildings and infrastructure or other applicable mitigations in areas that may be threatened by future sea level rise as shown on maps released by the San Francisco Bay Conservation and Development Commission in February 2007." (EH-3.n)
- Amend the Marin County Code to include construction standards for areas threatened by future sea level rise." - AIR-5i
- "Analyze potential safety implications from sea level rise and prepare contingency plans in consultation with the Marin Disaster Council." - PS-1.2
- "Identify strategies to protect the economy from the impacts of sea level rise, natural disasters, and disease outbreaks." (EC-1.5)
- "Analyze risks to park resources from violent weather, plant and aquatic changes, and sea level rise, and prepare appropriate contingency plans." (PK-1.v)

As a revolutionary example of a local plan that combines strategies for achieving mitigation and adaptation, the *Marin Countywide Plan* has both set a high bar in preparing for sea level rise and established an example for other communities to follow.



## **A Final Thought in Moving Forward**

Much like the previous examples of King County, Punta Gorda, and Marin County, North Carolina's coastal communities are poised to take their place amongst the nation's leaders in sea level rise adaptation and preparedness. A solid framework already exists for implementing programs and actions in support of adaptation goals, such as those mentioned in Section 3. Fundamental changes, however, must first take place with the CAMA land use planning process itself if preparations are to be meaningful and effective. Additionally, a number of broad obstacles will need to be overcome to ensure optimal stakeholder support for adaptation initiatives.

In the worst case scenario, North Carolinians will adapt to changes in an ad-hoc manner as time advances and new knowledge about sea level rise becomes more apparent. If utilized, an early planned approach to sea level rise adaptation will spare the state and its residents of the high financial and social costs that would otherwise accompany an improvised response. Moving further ahead into an era of accelerated sea level rise that has already begun will necessitate expensive and potentially uncomfortable decisions from stakeholders in preparing for further dramatic changes to the physical coastal landscape. Planners are trained to avoid acting myopically by instead recognizing and creatively responding to long-term and interrelated consequences. By helping communities to avoid an era that would otherwise be characterized by disaster, planners in North Carolina and other coastal locales are poised to assume a leadership role of their own.

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